



Alfred Gessow Rotorcraft Center

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An All Electric Helicopter

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ELECTRIC POWERED HELICOPTER



ADVANTAGES:

- NO FOSSIL FUELS (LOW EMISSIONS)
- LOW MOTOR NOISE

DISADVANTAGES:

- BATTERY & MOTOR WEIGHT
- UNPROVEN TECHNOLOGY

DESIRABLE CHARACTERISTICS

- IN COMPARISON TO EXISTING HELICOPTERS,
SHOULD HAVE COMPARABLE PERFORMANCE,
PURCHASE PRICE AND DIRECT OPERATING COST



Boeing Research and Technology Europe (BR&TE) Fuel Cell Demonstrator



- Converted from a 2- seat Dimona Motor Glider
- Power from PEM Fuel Cell and Lithium ion Batteries
- During Take-off Both Batteries Provide Power
- During Cruise, Fuel Cell provides Power
- Take-off Weight = 1850 lb
- Weight of Fuel Cell = 205 lb (Dry)
- Weight of Water (Fuel) = 22 lb
- Cruise Power (at 62 mph) = 15 kW
- Approximate Capability 30 minutes Powered Flight





CURRENT FIXED WING EXPERIENCE



DIMONA MOTOR GLIDER





ELECTRAFLYER - C



Single Seat Electric Powered Aircraft

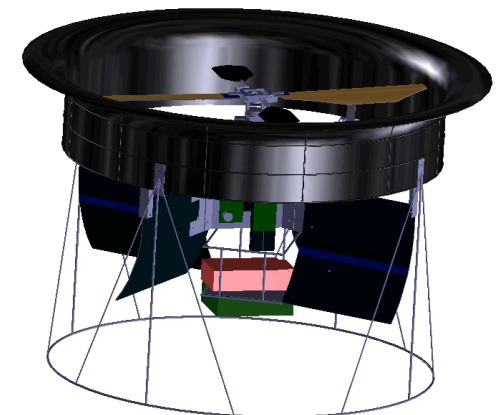
Take-off Weight	625 lb (283 kg)
Empty Weight	380 lb (172 kg)
Cruise Speed	70 mph
Maximum Speed	90 mph
Power Required	200 Amps climb, 50 Amps cruise
Endurance	90 min
Battery	2 * 75 Volt Lithium Polymer, 5.6 kW
Battery weight, cost	78 lb, \$8500
Motor	Direct Drive Brushed 18 hp (13.5 kW)



ELECTRIC HELICOPTERS: RC MODLES

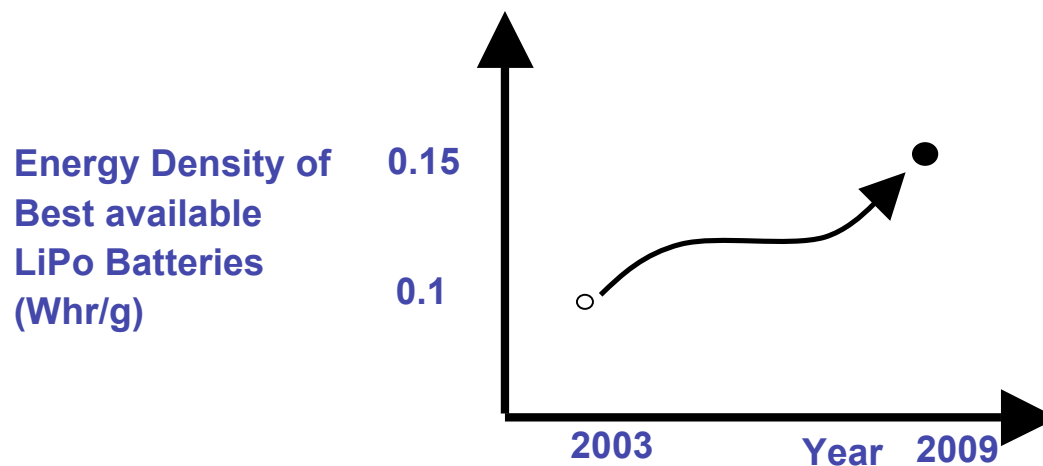
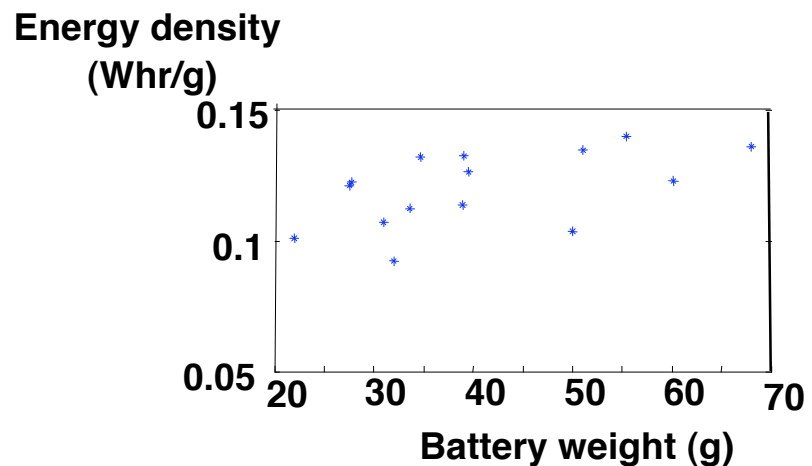
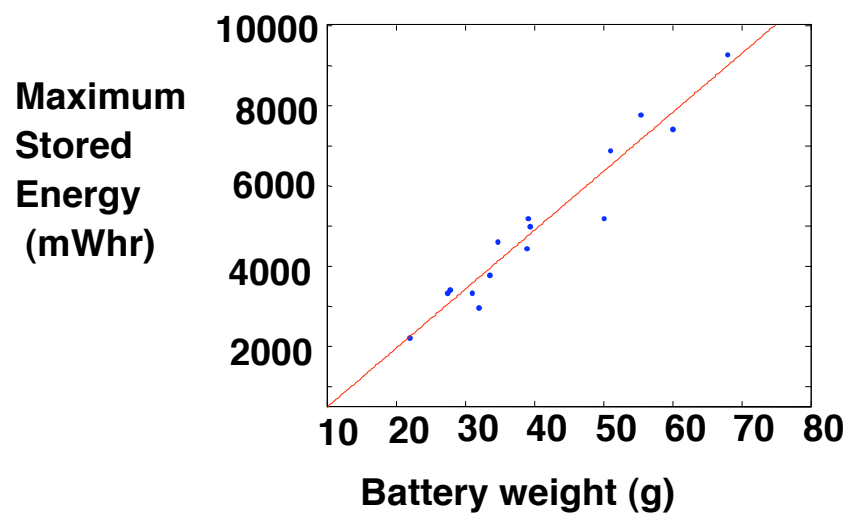


- Radio controlled Model Helicopters are a Fast Growing Market
- Trend: Low cost, Easy to fly, Maneuverable Models
- Maximum weight about 10 lb
- Maximum Endurance: 5 to 15 minutes
- Endurance Limited by Battery Capability





Performance of Lithium Polymer Batteries





Feasibility Study of All-Electric Robinson R-22 Helicopter



Characteristics of Light Helicopters



Helicopter	Take-off Weight lb	Number of Passengers	Cruise Speed (knots)	Power (shp)	Power Loading (lb/shp)
Robinson R22 Beta	1370	2	96	160	8.56
Robinson R44	2400	2+2	110	254	9.45
Schweizer 300CB	2050	2	78	180	11.39
<i>Electra Flyer – C (FIXED WING)</i>	625	1	60	40	15.62



DOC and Price of some Helicopters



Helicopter	Direct Operating Cost, \$/Flight Hour	Price (New) \$Million
Bell 206B Jetranger	281.74	1.25
Robinson R22 Beta	90.80	0.21
Robinson R44	124.73	0.31
Schweizer 300CBi	90.58	0.24



ROBINSON R-22 BETA 2 HELICOPTER



Gross Weight 1300 lb, 2 Seater



FEASIBILITY STUDY

ALL ELECTRIC ROBINSON R-22



BASELINE ROBINSON R-22 HELICOPTER

- 2- Place Piston Engine Helicopter
- Engine: Lycoming O-320-B2C
- Take-off Power: 160 hp (119 kW)
- Maximum Continuous Power: 124 hp (93 kW)
- Engine Weight 277 lb
- Helicopter Weights:
 - Maximum Gross Weight 1300 lb
 - Empty Weight 796 lb
 - Fuel Weight 115 lb
 - Useful Load with Full Fuel 390 lb
- Cruise speed 96 knots
- Maximum Endurance 3 hours



FEASIBILITY STUDY: ALL ELECTRIC ROBINSON R-22: Replacement Components



ENGINE AND TRANSMISSION RELATED WEIGHTS

- PISTON ENGINE	277 LB
- ENGINE INSTALLATION, CONTROLS	47 LB
- MAIN ROTOR TRANSMISSION	68 LB
- TRANSMISSION INSTALLATION, MOUNTS, STRUCTURE	49 LB
- TAIL ROTOR GEARBOX	5 LB
- FUEL SUPPLY SYSTEM	11 LB
- FUEL WEIGHT	115 LB

TOTAL WEIGHT OF POWERPLANT, TRANSMISSION AND FUEL	572 LB
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ELECTRIC R-22: ASSUMPTIONS



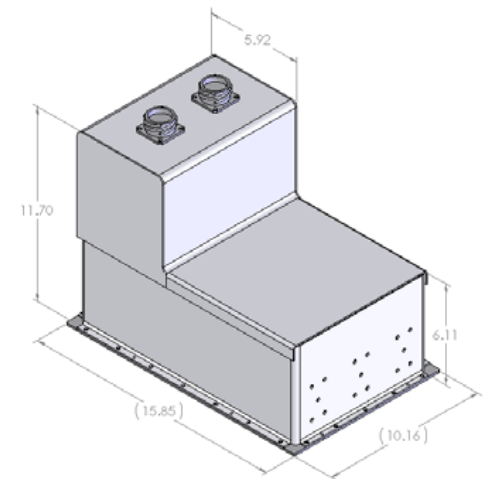
- 1. SAME AIRFRAME AND ROTOR SYSTEM AS PISTON ENGINE BASELINE HELICOPTER**
- 2. REPLACEMENT ENGINE, TRANSMISSION AND FUEL WITH ELECTRIC MOTOR AND BATTERIES**
- 3. ELECTRIC MOTOR PROVIDES BASIC FEATURES:**
 - PEAK POWER OUTPUT = 160 HP (119 KW)**
 - CONTINUOUS POWER = 90 HP (67 KW)**
 - ENERGY STORAGE REQUIRED FOR ONE MIN TAKE-OFF + CRUISE**
- 4. ELECTRIC MOTOR (GE: ADVANCED TORPEDO)**
 - MOTOR AND GEAR BOX = 130 LB (59 KG), POWER=161 HP**
 - OPERATING VOLTAGE = 300 VOLTS, ARMATURE SPEED=20,000**



POWER SOURCE



- **SURVEY OF ELECTRIC POWER SOURCES SHOWED: SUITABLE SOURCE IS A LITHIUM-ION BATTERY**
- **LITHION 9553 HV BATTERY DEVELOPED BY LITHION FOR NASA X-37 REUSABLE SPACEPLANE APPROACH AND LANDING TEST VEHICLE**
- **BATTERY CHARACTERISTICS**
 - Nominal output Voltage 150 V
 - Maximum Continuous Current 80 A
 - Ampere-hour Capacity 12 Ah
 - Weight 57.9 lb
 - Dimensions H: 11.7", W: 10.16", D: 15.85"
 - Cell-level Specific Energy 125 Wh / kg
 - Battery Level Specific Energy 69 Wh / kg or .069 kWh/kg

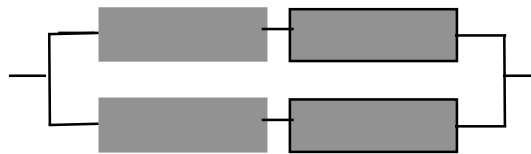




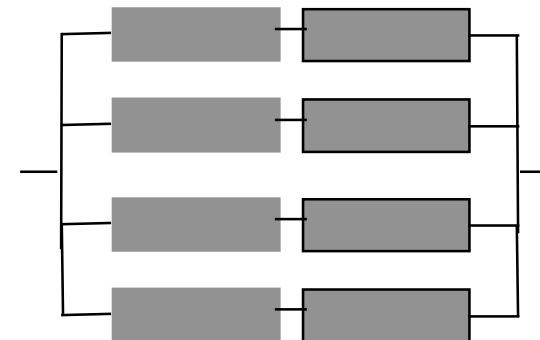
SCHEMATIC ARRANGEMENT OF BATTERIES



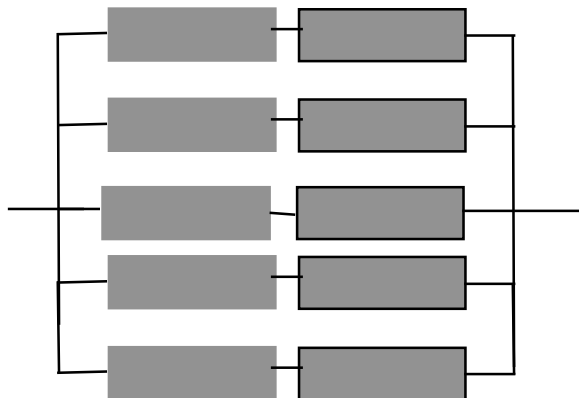
TWO BATTERIES
(3.63 kilowatt-hours
Weight = 115.8 lb)



FOUR BATTERIES
(7.26 kilowatt-hours
Weight = 231.6 lb)



EIGHT BATTERIES
(14.51 kilowatt-hours
Weight = 463.2 lb)



TEN BATTERIES
(18.14 kilowatt-hours
Weight = 579 lb)

***WEIGHT OF ELECTRIC MOTOR, CONTROLS, INSTALATION (= 155 LB) IS
CONSTANT FOR ALL BATTERY ARRANGEMENTS***



PERFORMANCE COMPARISON



BASELINE

Electric

Electric

Electric

Electric

Number of Passenger	Battery Packs	Take-off Weight, (lb)	Endurance (minutes)
1+1	PISTON ENGINE	1300	180
1+1	4	1115	5.3
1	4	919.6	6.5
1	8	1151	10.4
1	10	1267	11.8



SUMMARY COMMENTS



- FEASIBILITY STUDY TO REPLACE PISTON ENGINE WITH ELECTRIC POWER FOR ROBINSON R-22 WAS CONDUCTED
- PACKS OF LITHION 9553 HV BATTERY AND GE ALWT MOTOR USED TO REPLACE PISTON ENGINE AND GEAR BOX.
- BASELINE R-22 (TAKE-OFF WEIGHT = 1300 LB) HAS ENDURANCE OF 3 HOURS. ELECTRIC VERSION (TAKE-OFF WEIGHT = 1267 LB) HAS ENDURANCE OF 11.8 MINUTES
- ENERGY OF 10 LITHION 9553 BATTERY PACK IS 18 KILOWATT HOUR. ENERGY OF PISTON ENGINE/FOSSIL FUEL FOR 3 HOUR ENDURANCE IS 281 KILOWATT HOUR



TECHNOLOGY CHALLENGES



- ENERGY DENSITY OF STATE-OF-ART ELECTRIC POWER SOURCE IS 0.07 kWh/Kg
- 8 TO GIVE SAME PERFORMANCE AS BASELINE PISTON ENGINE/FOSSIL FUEL REQUIRED ENERGY DENSITY SHOULD BE 1.09 kWh/Kg
- ELECTRIC POWER SOURCE MUST BE COMPACT TO FIT INTO HELICOPTER AIRFRAME
- ELECTRIC MOTORS ARE HEAVY. THESE NEED TO BE COMPACT AND LIGHT



RECOMMENDATIONS



ELECTRIC:

- DEVELOP ELECTRIC POWER SOURCES WITH LOW VOLUME AND HIGH ENERGY DENSITY
- DEVELOP SMALL SIZE, LOW WEIGHT ELECTRIC MOTORS

VEHICLE DESIGN:

- INNOVATE DESIGN USING MODERN TECHNOLOGY.
HYBRID VEHICLE COMBINING HOVER PERFORMANCE OF ROTARY-WING WITH FORWARD FLIGHT PERFORMANCE OF FIXED-WING

CONTROLS:

- SWASHPLATELESS & AUTONOMOUS